EXECUTIVE SUMMARY

CARBITS is a market simulation model for the personal vehicle market in California. Professor David S. Bunch developed CARBITS for the ARB during 2003-2004 under a contract with the University of California, Davis. Its primary purpose is as a scenario analysis tool to evaluate market response under alternative regulation scenarios. For purposes of this Final Report, the version of CARBITS developed during 2003-2004 will be referred to as "CARBITS 1.0." CARBITS 1.0 was commissioned by the ARB to meet specific needs for their work under AB 1493 regulating motor vehicle greenhouse gas emissions, and was developed under a short time frame. For practical reasons, it was based on an existing model developed under an earlier University of California-Institute of Transportation Studies research program. Although time and monetary constraints prevented development of a full range of features, ARB staff successfully used CARBITS 1.0 in support of the climate change regulation adopted by the Board in September 2004.

Experience in working CARBITS as part of the 1493 rulemaking process led to some ideas for potential improvements. The overall stated objective of this project is to update and extend existing CARBITS model based on these experiences. Briefly, the stated goals of this project are:

1. Estimate new vehicle choice models using more recently collected datasets.
2. Address issues of statistical noise and runtimes.
3. Specifically address the issue of vehicle market exit/scrappage.
4. Develop re-calibration procedures to update certain model constants based on aggregate-level vehicle counts.
5. Include the capability to address hybrid electric vehicles

To illuminate these goals, we first review some details about CARBITS 1.0. As noted, CARBITS 1.0 was created using a pre-existing model. During the period 1992-1995, a team of Institute for Transportation (ITS) researchers at University of California (Davis and Irvine campuses) pursued a multi-year research program involving data collection and vehicle choice modeling. The California Energy Commission (CEC) provided much of the motivation for this work, which was targeted at exploring the future market for alternative fuel vehicles in California, including: battery-powered electric vehicles, compressed natural gas (dedicated and dual fuel versions), and alcohol/flex fuel. A major task was fielding a panel survey of California households that included stated choice questions on alternative fuel vehicles. One research goal was to explore household demand models based on *transaction* choices (e.g., vehicle replacement, addition, or disposal decisions) as an alternative to vehicle *holdings* models (the usual state of practice). The results of this project were used to develop CARBITS 1.0 to meet the needs of ARB.

The experiences and insights gained during the development and use of CARBITS 1.0 led to a number of ideas that were the motivation for this project. We briefly review

these here. More details are included in the main report. First, from the very beginning of the earlier project, concerns were raised about the dataset being "old." This is a standard criticism for any model like CARBITS, given the expense and difficulty of collecting large-scale data sets on a regular basis. Regardless of whether there are technical merits to this narrow argument, it provides an opening to criticism by hired consultants. Second, the transactions models adapted from the earlier research required the use of pure microsimulation. This means that the model does not produce deterministic, analytical results, and it also requires special expertise (and long run times) to produce results in the proper manner. One example of why this can be an issue occurred during the 1493 rulemaking. Auto industry consultants (either accidentally or intentionally) produced results using CARBITS 1.0 that did not use enough replications to produce stable results, and then used these in an attempt to undermine CARBITS. A more practical concern is that using CARBITS 1.0 requires very long run times, making analysis more burdensome to the user.

A related issue is that the original modeling approach was primarily concerned with evaluating the entry of new types of vehicles (none of which, by the way, were hybrid electric—see below), with much less emphasis on vehicle exit and scrappage. CARBITS 1.0 takes an approach where vehicles exit the market "implicitly," based on the dynamics of vehicle replacement. In contrast, other approaches use aggregate data to estimate models that explicitly address vehicle exit. There are pros and cons to each method; however, because the latter method is easier to understand, it is typically used by outside consultants. Moreover, the AB 1493 experience suggests that a more complex model like CARBITS is vulnerable to criticism through both misapplication of the model and misrepresentation of results. Finally, there is the issue of hybrid electric vehicles. The recent penetration of hybrid electric vehicles makes it obvious that future policy analyses may need to address this new type of vehicle.

These specific goals listed above been addressed by this project. With regard to introducing new data, various options were considered. Maintaining and updating CARBITS 1.0 as a transactions-based model would require a new source of household panel data that includes details on vehicle transactions. This type of data is very expensive to collect and difficult to come by. Moreover, experience suggested that the transactions-based approach was the common source of a number of the issues this project was intended to address. Based on multiple factors, we decided to update CARBITS using the 2000-2001 Caltrans Statewide Travel Survey.

These data (although a few years old) are attractive for a number of reasons. For a household survey of this type it has a very large sample size (over 17,000 households, all from California), and uses high-quality sampling and weighting procedures. In conjunction with using these data (which include information on vehicle holdings, but not transactions), CARBITS was converted from a transactions microsimulation model to a vehicle holdings model. This approach directly addresses the issue of statistical noise and run times, since holdings models can be implemented using analytical computations that yield deterministic (noise free) results requiring relatively short run times.

Although it is less than obvious from the stated project goals, the decision to estimate a completely new model for CARBITS (regardless of which household dataset was chosen) created a whole host of additional data requirements. Substantial effort was invested in data compilation and cleaning for this project. One area requiring a large amount of work was the development of a Vehicle Technology Database. Vehicle choice models have a number of requirements for characterizing the vehicle choices faced by consumers in the marketplace. These include such things as market prices, vehicle body types and sizes, fuel economy, performance characteristics, and others. No one data source includes all of these information items. This requires creating a large database by merging together data from multiple data sources. Because each data source has its own way of defining vehicles (which includes character string data describing the make and model of vehicle), cleaning and merging these data is a herculean task.

In addition to vehicle technology data, there are multiple aspects of the project that require aggregate data on multiple aspects of the vehicle market. For example, models like CARBITS (which are estimated on the basis of household survey data) must periodically be re-calibrated so that the vehicle distributions for the model base year match the aggregated vehicle totals from an outside source (project goal 3). In addition, estimating a model of vehicle exit requires some type of data set that tracks the entry and exit of vehicles from the market (project goal 2). Finally, in recent years hybrid electric vehicles have been entering the market. Survey data cannot possibly have the sample size to obtain accurate measurements of this aggregate phenomenon (project goal 4). To address these data needs, procedures for processing Department of Motor Vehicles (DMV) registrations data were developed.

We emphasize the data collection and cleaning aspect of this project because (i) a substantial amount of the contract effort was devoted to it, and (ii) we consider the outcome of this effort to be a major side benefit of this project that goes beyond the narrow statement of the project goals. In a similar vein, our approach to creating the new version of CARBITS ("CARBITS 2.0") incorporated system design concepts such as object-oriented analysis and object-oriented programming. Specifically, rather than program CARBITS 2.0 as a stand-alone one-time effort, we decided to create a generic system framework for "CARBITS-like models," and then implement CARBITS 2.0 as a specific "instance" within this framework. The system framework and CARBITS 2.0 were implemented using the object-oriented features of MATLAB. (In contrast, CARBITS 1.0 was written in FORTRAN.) This approach will make any future efforts to modify or update CARBITS much easier.

To summarize, the project outcomes include the following:

1. CARBITS was updated using a more recent data set (2000-2001 Caltrans Travel Survey)
2. CARBITS was converted to a holdings-based model from the original transactions-based model.

3. Outcomes 1 and 2 directly address the issue of model runtimes and statistical noise by using an approach that produces results based on deterministic computations.
4. DMV data were developed as a source of data on aggregate vehicle counts, vehicle entry and exit statistics, and penetration of hybrid electric vehicles.
5. Outcome 4 supported the development of procedures to re-calibrate model constants to match aggregate vehicle totals, the estimation of a vehicle market exit model, and the capability to incorporate data on hybrid electric vehicles.
6. A substantial amount of effort on compiling and cleaning data (including many data sets on vehicle prices and technology) yielded an additional side benefit for future work by ARB.
7. CARBITS 2.0 was developed using object-oriented analysis and programming methods. A generic system framework for "CARBITS-like models" was established, and then CARBITS 2.0 was coded as a special case.

BACKGROUND

In late 2002, ARB staff approached the Institute of Transportation Studies (ITS) at University of California, Davis (UC Davis) to discuss a number of research needs related to its charge to perform rulemaking under AB 1493 (Pavley). One such need was for a scenario analysis tool to provide a quantitative assessment of the effects of alternative regulatory policies on the personal vehicle market in California over the medium and long term. For example, manufacturers would be expected to change their vehicle offerings in order to comply with a regulation. The operating characteristics, and new vehicle prices would be expected to change. This, in turn, would elicit a response from the vehicle market. Prof. David S. Bunch agreed to develop such a model under as part of a larger research project performed during 2003-2004. Both time and budget requirements precluded a major research effort, e.g., fielding a household survey, collecting data, and developing an entirely new model. The proposed solution was to adapt models developed under an earlier research program.

The earlier research involved data collection and vehicle choice modeling for the California market. It was performed during the mid 1990's by a team of ITS researchers (including Prof. Bunch) from two University of California campuses (Davis and Irvine). The program was a multi-year effort with funding from multiple sources. The California Energy Commission provided much of the motivation for this work. In addition to funding a pilot project, they coordinated efforts for a sequence of projects funded first by Southern California Edison, and then Pacific Gas & Electric. In addition, the research team received pass-through federal funding from the ISTEA program.

One component of the project was a panel survey of California households. The desire was to get observations from the same household at multiple points in time in order to trace the transaction dynamics of their vehicle purchases. In addition, the survey involved the application of stated preference methods to collect data on hypothetical choice of alternative fuel vehicles, including battery-powered electric vehicles, compressed natural gas (dedicated and dual fuel versions), and alcohol/flex fuel. The two